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Statement of Problem.

Anthropometry is becoming a widespread practice. This is partly because of its importance in physical child development, and partly because of the relations which Kretschmer ('26) pointed out between body build and temperament in psychiatric state. Also, the comparative study of races by anthropologists depends largely upon anthropometry.

PART I. EXTRINSIC ERRORS IN ANTHROPOMETRY.

Anthropometric method is still far from being in a satisfactory state. Fortunately, we have standard apparatus and the difficulty does not lie here, although no doubt new kinds of apparatus will be eventually devised for the measurement of particular dimensions. The largest error perhaps lies in the determination of particular landmarks. This is a matter upon which Richard H. Post ('31) has published a study, after visiting many of the principal anthropometrists of this country and Europe.

A matter that has not been sufficiently investigated is the error due to differences in posture of the subject, dependent upon the time of day, and fluctuations depending upon the psychological and physiological state of the subject. The latter point particularly needs to be stressed. The muscles of the body indeed modify the distance between landmarks, and anthropometry is accordingly concerned partly with the neuro-muscular mechanism and tone of muscles. It is hardly an exaggeration to say that anthropometry is within limits a form of psychometry.

Finally, slight variation in technique due to differences in pressure applied to the skin overlying skeletal points, or in girths, has not been sufficiently considered. It is to be hoped that all of these variations in technique will be reduced through the activities of the Anthropometric Committee of the International Federation of Eugenic Organizations.

Method and Material.

In order to get some light upon the differences in results due to variations in the subject and slight differences in technique (personal equations) a series of measurements was made by a single measurer (M. S.) on a single subject (R. M.), who was measured fifty consecutive times at different times of the day through a number of days. It was hoped to get answers to the following questions: (a) What variations occur in successive measurements by one person of one subject in a short period of time? These variations may be due to (1) differences in the neuro-muscular condition of the measurer, (2) variations of the neuro-muscular state of the subject. (b) What effect has the time of day? This was determined by comparing morning and evening measurements. (c) What effect on measurement has the clothing? This was investigated by having the same subject wear at one time a tightly fitting bathing suit and at other times the usual indoor clothing. The differences between the right and left sides of the subject were also studied.

The dimensions measured were (1) weight, (2) stature, trunk and appendages, (3) sitting height (spine in the same posture as standing), (4) biacromial width, (5) intercristal width (skin hardly indented), (6) interspinal width (between middle points of anterior sup. il. spine), (7) transverse chest at fifth ribs, (8) anterio-posterior chest diameter, (with straight armed calipers), (9) chest girth, perpendicular to spine at axilla, (10) acromial height, from floor, (11) radiale height, (12) stylial height, (13) dactylial height, from floor, (14) acromion to stylion, measured direct with calipers, (15) acromion to radiale, with calipers, (16) radiale to stylion, (17) span, subject with back to wall and anthropometer behind subject, (18) iliospinal height, (19) tibiale height, (20) tibiale to sphyrion, direct measurement, (21) hand length, from tracings, which averaged 8.7 mm. greater than direct measurement, (22) hand width, (23) foot length, (24) foot width, (25) upper arm girth, (26) lower arm girth, (27) minimum forearm girth, (28) wrist girth, (29) calf girth, (30) ankle girth. Head and face: (31) head girth, (32) neck girth, (33) head length, (34) head width, (35) bizygomatic width, (36) minimum frontal, (37) bigonial width, (38) nasion to subnasion, (39) nose breadth, (40) nose depth, (41) trichion to gnathion, (42) nasion to gnathion, (43) nasion to stomion, (44) pinna length, (45) pinna width, (46) outer eye angles, (47) inner eye angles, (48) mouth width, (49) lip thickness.

Results.

A. Variations in Accuracy of Measurements.

Table I gives the summary of the results obtained by M. S. in measuring R. M. These results are measured by the inaccuracy of

TABLE I.

SHOWING THE RESULTS OBTAINED BY M. STEGGERDA IN MEASURING R.M.

Dimension	Mean	σ	P.E. Single Meas.	C.V.
Stature	1672.23 mm.	3.10 mm.	2.09 mm.	.19%
Head lgth.	194.24	.43	.29	.22
Bizygomatic bdth.	130.88	.32	.22	.24
Supst. Ht.	1358.92	3.52	2.37	.26
Head Bdth.	146.30	.46	.31	.31
Head Girth	572.84	1.86	1.25	.33
Span	1612.77	6.72	4.53	.42
Net arm lgth. (Subt.)	523.80	2.42	1.63	.46
R. Acromion Ht.	1362.00	6.38	4.30	.47
Acromion to Stylion	522.96	2.56	1.73	.49
Sitting Ht.	905.08	5.36	3.62	.59
R. Foot (Direct)	253.60	1.54	1.04	.61
R. Iliospinale Ht.	910.31	5.70	3.84	.63
R. Radiale Ht.	1065.85	8.14	5.49	.76
R. Tibiale Ht.	441.36	3.37	2.27	.76
R. Stylion	836.15	6.48	4.37	.78
Neck Girth	320.34	2.57	1.73	.80
Weight in lbs.	138.85	1.17	.79	.84
R. foot lgth. (Tracing)	256.16	2.27	1.53	.89
Chest Girth	852.32	7.78	5.25	.91
Tibiale to Sphyrion Ht.	359.92	3.29	2.22	.91
R. lower Arm Girth	231.70	2.21	1.49	.95
R. Dactylion Ht.	662.77	6.36	4.29	.96
Bigonial Bdth.	101.52	.98	.66	.97
Sitting Supst. Ht.	589.08	5.96	4.02	1.01
Intercristal Bdth.	301.48	3.13	2.11	1.04
Trichion to Gnathion	180.44	1.89	1.27	1.05
Minimum Frontal Bdth.	106.76	1.12	.76	1.05
Wrist Girth	144.32	1.53	1.03	1.06
Gross Arm Lgth. (Subt.)	697.96	7.50	5.06	1.07
Vertex Ht.-Supst. Ht.	312.84	3.56	2.40	1.14
R. Ankle Girth	209.12	2.47	1.67	1.18
Chest A.P.	200.76	2.40	1.62	1.20

TABLE I. (Cont.)

SHOWING THE RESULTS OBTAINED BY M. STEGGERDA IN MEASURING R.M.

Dimension	Mean	σ	P.E. Single Meas.	C.V.
Acromion to Radiale (Direct)	294.04	3.64	2.46	1.24
Chest transverse	271.08	3.50	2.36	1.29
R. Hand Lgth. (Direct)	172.50	2.26	1.52	1.31
Nasion to Gnathion	121.54	1.59	1.07	1.31
External Eye Angles	96.36	1.31	.88	1.36
R. Minimum Forearms	150.06	2.07	1.40	1.38
Radiale to Stylion (Direct)	227.96	3.26	2.20	1.43
R. Calf Girth	325.52	4.71	3.18	1.45
Waist Girth	734.96	10.81	7.29	1.47
R. Hand Lgth. (tracing)	181.24	2.70	1.82	1.49
R. Upper Arm Lgth. (Subt.)	296.92	4.53	3.06	1.53
Acromion Bdth.	353.56	5.46	3.68	1.54
R. Hand Breadth (Direct)	76.34	1.21	.82	1.59
R. Hand Breadth (tracing)	77.90	1.25	.84	1.60
Inner Eye Angles	33.82	.59	.40	1.74
R. Lower Arm Lgth. (Subt.)	228.28	4.45	3.00	1.95
Nasion to Stomion	78.34	1.53	1.03	1.95
Nose Bdth.	31.34	.65	.44	2.07
Trochanter Bdth.	346.48	7.42	5.00	2.14
R. Ear Lgth.	67.00	1.47	.99	2.19
R. Upper Arm Girth	273.96	6.15	4.15	2.24
R. Foot Bdth. (Direct)	88.16	2.07	1.40	2.35
Malleolus Ht.	74.72	2.04	1.38	2.73
Interspinal Bdth.	263.04	7.20	4.86	2.74
Nose Height	56.34	1.57	1.06	2.79
Mouth Width	49.14	1.47	.99	2.99
R. Foot Bdth. (tracing)	91.14	2.94	1.98	3.23
R. Ear Bdth.	34.04	1.13	.76	3.32
Nose Depth	27.64	1.31	.88	4.74
Lips	17.08	.84	.57	4.92
Nose Salient	20.84	1.50	1.01	7.20
Nose Bridge Ht.	14.68	1.65	1.11	11.24

the result; the least inaccurate, as measured by the coefficient of variation (C. V.), being placed at the top of the table. From this coefficient of variation it appears that some of the larger measurements, like stature, suprasternale height, span, sitting height, show variability mainly because the dimensions are large. And in these

cases the probable error in the measurement of a single dimension is often considerable. On the other hand, the highest coefficients of variation are generally for small dimensions as, for example, height of the nose bridge, with a coefficient of variation of 11%; the nose salient with a coefficient of variation of 7%; width of the lips with a coefficient variation of 5% and nose depth with a coefficient variation of 4.7%, and so on.

There are some measurements which have a small coefficient of variability despite the small dimensions. These must be regarded as essentially accurate measurements. Such are head length, bi-zygomatic breadth, head breadth, foot length, bigonial breadth, and minimum frontal breadth. On the other hand we found, as did Dahlberg ('26, p. 198), that some of the probable errors of measurement are small even when the dimensions are large, which indicates a high degree of precision in the measurement. For example, there is total stature, of which the probable error of measurement is only 2 mm., giving a coefficient of variation of .19%. Again, span gives a probable error of 4.5 mm., a variation coefficient of .42%. This is an inaccuracy somewhat greater than that of the stature on a mean measurement which is about the same, but this has an error of the single measurement of only 4.5 mm. out of a total of 1,613 mm.

Among the measurements that must be regarded as rather low in accuracy is the length of the lower arm as determined by subtraction from projected radiale height of projected stylion height from the floor. This has an average error of the single measurement of 3 mm., out of a total of 228 mm. In general, the lengths of the projections of the arm, as determined by measurements from the floor, have a low order of accuracy, or at least a large error for the single measurements. Also inaccurate are waist girth, chest girth, bi-acromial breadth, bi-cristal breadth, trochanter breadth, interspinal breadth, sitting suprasternal height, upper arm girth.

The determination of arm length, by measuring from the floor, is inaccurate on account of the tendency of the shoulders to sway during the measuring. The accuracy of measurement of these dimensions of the arm can be increased if one begins by determining the right acromial height from the floor, measures the remaining points on the arm in rapid succession and then returns to the right acromial height. If the first and second acromial heights check within 2 mm. then the measurements as recorded are accepted as correct. If the second measurement of the right acromion is more than 2 mm. different from

the first the measurements are repeated, and so on until the difference does not exceed 2 mm.

The error in bi-acromial breadth is probably due partly to variations in posture of the scapulae (which are, of course, highly mobile), partly to variation of pressure upon the bony landmarks, and partly to variations in the manner in which the operator holds the calipers. Variations in intercristal breadth are due in part to the fact that the landmarks are not defined points, but merely tangents to curves. Variations in sitting suprasternale heights are due in part to variations in general posture of the individuals and, above all, to the degree of inflation of the lungs, which modifies the suprasternale height. Variations in girth of the trunk are partly due to the act of respiration. At best these dimensions can be only an average of a number of measurements taken at different phases of respiration.

Trochanter breadth has a high inaccuracy which is a little difficult to account for. In interspinal breadth, error is due to the fact that the landmarks instead of being "points" are "knobs" and it is not always possible to determine the center of the knob. The error in right upper arm girth may be diminished by taking the girth always at a point where the belly of the bicep muscles are thickest, about half way between the acromion and the radiale.

B. REDUCTION IN HEIGHT FROM MORNING TO EVENING.

In the case of the 50 repeated measurements by M. S. on R. M. it appears that the following dimensions listed in Table II are most affected by the hour of the day at which they are taken:

TABLE II.

LIST OF DIMENSIONS WHOSE LENGTH IS MOST AFFECTED BY TIME OF DAY, AND MEASUREMENTS MADE ON THEM.

Dimension	A.M.	P.M.	Δ	P.E. Δ	Δ/P.E. Δ
Stature	1672.23	1664.83	7.40	.57	12.98
Suprasternale Ht.	1358.92	1352.42	6.50	.80	8.13
Sitting Ht.	905.08	895.83	9.25	1.46	6.34
Sitting Supst. Ht.	589.08	581.50	7.58	1.92	3.95

The successive measurements of the same person at different times of the day showed, as we have seen, a loss in stature of 7.4 mm. from morning to afternoon and a loss in sitting height of 9.2 mm. in the same period. It might seem remarkable that the loss should be the

greater in the sitting height (involved as it is in stature). But anyone who has had extensive experience in measuring sitting height knows that the act of sitting, as contrasted with standing, brings quite new muscles to play upon the posture of the trunk and demands special control of, and tone in, those muscles. For we are habituated to erect standing and to a slumping sitting posture. The loss of stature during the day is probably quite as much due to loss of "tone" as of thickness of intervertebral pads.

This discernible loss of stature and sitting height has long been noticed. Nylin ('29, p. 35–37) and Boyd ('29, p. 394–396) have recently brought together the literature on this subject so it will not be necessary to review it again. Most authors find a decrease in stature of around 20 mm. from rising in the morning until bed time. In the present series of measurements, probably not more than 6 hours intervened between the first and second measurement; and there was a rest period (lunch hour) in the middle. Also the measurements were all made from 2 to 8 hours after rising in the morning; thus, in the middle of the day when change is least rapid.

C. UNSYMMETRICAL BODILY DIMENSIONS.

The following dimensions proved to be significantly unequal on the two sides of the subject. The average differences in mm. is given and the difference is also expressed in units of the probable error.

TABLE III.

MEASUREMENTS OF WHICH THOSE ON THE RIGHT SIDE ARE LESS THAN ON THE LEFT; WITH DIFFERENCES AND PROBABLE ERROR OF THE DIFFERENCE.

	mm.	$\frac{\Delta}{P.E._\Delta}$		mm.	$\frac{\Delta}{P.E._\Delta}$
Acromion to stylion (direct)	1.2	2.9	Upper arm girth	1.9	2.4
Acromion to radiale (subt.)	4.5	8.9	Foot length (traced)	1.6	4.8
Iliospinale height	14.4	13.9	Lower arm girth	1.6	5.3
Tibiale to sphyrion	4.0	10.2	Min. forearm girth	.9	3.0
Hand length (traced)	4.4	12.1	Wrist girth	2.2	9.7
Hand width (traced)	1.3	6.9	Calf girth	2.7	4.1
Foot length (traced)	1.6	4.8	Ankle girth	3.6	11.2

D. EFFECT OF CLOTHING ON BODILY MEASUREMENT.

TABLE IV.

DIMENSIONS THAT ARE AFFECTED BY THE AMOUNT OF CLOTHING WORN:

	Time	Ordinary Indoor Clothing	Bathing Suit	Difference	P.E.D.	D/P.E.D.
R. Acromion Ht.	A.M.*	1369.85	1362.00	7.85	1.27	6.18
Sitting Ht.	A.M.*	909.85	905.08	4.77	1.33	3.59
Radiale Ht.	A.M.*	1071.38	1065.85	5.53	1.74	3.18
Tibiale Ht.	A.M.*	434.56	441.36	6.80	1.24	5.48
R. Stylion Ht.	A.M.*	841.69	836.15	5.54	1.56	3.55
R. Dactylion Ht.	A.M.*	668.77	662.77	6.00	1.63	3.68
Sitting Supst. Ht.	A.M.*	594.62	589.08	5.54	1.62	3.42
Ankle girth	A.M.† P.M.†	210.64	209.12	1.52	.47	3.25
Calf girth	A.M.† P.M.†	329.20	325.52	3.68	.83	4.43
Trochanter bdth.	A.M.† P.M.†	341.24	346.48	5.24	1.40	3.74

* 13 observations.
† 25 observations.

It is rather remarkable that so little difference was found between measurements of certain dimensions made on the skin (or tightly fitting bathing suit) and over ordinary house clothing (without shoes). However, some measurements seemed to be seriously affected, e. g. acromial height, tibiale height and calf girth. Since most of the dimensions listed in the foregoing table are little covered by clothing (except trochanter breadth) the differences are probably not due to the thickness of cloth but to an obscuration of the landmarks. Thus, in acromial height the thickness of the dress over the shoulder is negligible, but since the point is difficult to locate with precision under the best of conditions the covering of the skin increases that difficulty —removes the aid of one sense (sight) in locating this landmark. Similarly, with the arm points. The radial "dimple" helps to locate radiale by sight, but hardly to touch. While it is gratifying to know that so accurate results can be obtained over clothing (as is so often necessary) for the most accurate comparative studies, as in growth of children, a minimum of clothing affords best conditions.

Summary of Part I.

1. Stature and sitting height were significantly greater in the morning than they were in the evening.

2. A woman's indoor clothing does not appreciably affect the significance of the measurement, but in several instances it does obscure the location of the point measured.

3. Tracings of hands and feet were significantly larger than measurements taken directly by calipers.

4. The diameters of the head are easily measured with a probable variation in repeated measurements of less than 1 mm.

5. Certain dimensions have a high variability with a probable error of single measurements of 5 mm. or more. These are: waist girth, chest girth, projective arm measurements taken from the floor, trochanter breadth (contour).

6. The results of most of these measurements show that this subject was significantly larger on her left side than on her right.

PART II. INTRINSIC ERRORS: THE PERSONAL EQUATION

Eleven adults were measured during morning hours between 9:30 and 11:30 o'clock by both C. B. D. and M. S. They were all measured in bathing suits. There were five men and six women. In each subject the dimensions were measured twice, all the measurements being made first upon a subject and then immediately repeated again on the same subject. During the interval the measurer had probably forgotten his findings at the first measurings.

Table V gives the percentage of inaccuracy of the different measurements made.* These are arranged in the first column in order of size as determined by M.S. Columns 4 and 5 give the findings of C.B.D. The mean differences in the findings of the two measures are given in column 2. That is, the first and second measurement for each of 11 subjects was averaged for each measurer (M.S. and C.B.D.). From the average for M.S. was subtracted the average for C.B.D. taking signs into account. The algebraic mean of these differences is thus given in column 2. They refer to the dimensions listed in column 1.

It will be observed that the measurements of M.S. are, on the whole, more accurate than those of C.B.D., which is probably in part

*Determined by dividing the quadratic mean of the differences x 100 by mean of measurements. Quadratic mean is the square root of the difference between each pair of measurements squared and summed for all differences ÷ number of individuals.

TABLE V.

ANALYSIS OF THE INACCURACY OF THE DIFFERENT MEASUREMENTS.

Col. 2. The average difference between the measurements of M.S. and C.B.D. for the dimensions in Col. 1.
Cols. 3, 4. Quadratic mean of differences divided by mean for meas. × 100.

1	2	3	4	5
Dimension				Dimension
Head Breadth	+ .32	.29%	.40%	Head Breadth
Stature	− .05	.43	.45	Maximum Head Girth
Head Length	+ 0.36	.48	.45	Sitting Height
Acromion Ht.	− 7.14	.50	.47	Stature
Radiale Ht.	−10.73	.55	.62	Span
Iliospinale Ht.	+ 3.68	.59	.71	Acromion to Stylion
Bizygomatic Bdth.	− 1.00	.61	.80	Nose Bridge Ht.
Maximum Head Girth	+ 3.64	.67	.81	Suprasternale Ht.
Acromion to Stylion	+ 6.23	.68	.81	Iliospinale Ht.
Trichion to Gnathion	+ 2.55	.70	.87	Ankle Girth
Sitting Ht.	− 2.00	.75	1.01	Acromion Ht.
Acromion to Radiale	+ 2.00	.75	1.04	Net Arm (Subt.)
Suprasternale Ht	− 1.95	.78	1.04	Head Length
Stylion Ht.	−13.95	.80	1.10	Radiale Ht.
Minimum Frontal Bdth.	− 1.14	.80	1.10	Tibiale to Sphyrion
Span	− 4.45	.81	1.13	Chest Girth (Axillary)
Bigonial Bdth.	+ 1.50	.87	1.20	Bizygomatic Bdth.
Net Arm Lgth. (Subt.)	+ 6.77	.96	1.27	Radiale to Stylion.
Neck Girth	− 2.05	1.04	1.34	Stylion Height
Ankle Girth	− 1.82	1.04	1.39	Sitting Supst.
Tibiale to Sphyrion	−12.55	1.22	1.60	Dactylion Ht.
Chest Girth (Axillary)	− 7.00	1.26	1.62	Tibiale Ht.
Upper Arm Girth	+ 3.73	1.32	1.66	Nasion to Gnathion
Radiale to Stylion	+ 0.95	1.33	1.71	Calf Girth
Dactylion Ht.	−16.14	1.37	1.73	Chest transverse
Calf Girth	− 1.68	1.41	1.82	Neck Girth
Minimum Forearm	− 3.09	1.45	1.87	Nasion to Stomion
Bi-acromion Bdth.	+ 5.82	1.49	2.00	Bi-acromion Bdth.
Lower Arm Girth	− 1.82	1.51	2.03	Bigonial Bdth.
Tibiale Height	− 2.77	1.52	2.06	Ear Height
Nose Bridge Ht.	− 1.86	1.59	2.14	Upper Arm (Subt.)
Lower Arm (Subt.)	+ 3.32	1.72	2.15	Minimum Frontal Bdth.
Nasion to Gnathion	+ 5.68	1.82	2.17	Vertex Ht. − Supst. Ht.
Chest transverse	−11.68	1.94	2.24	Dist. between ext. eye ∠s
Upper Arm (Subt.)	+ 3.59	1.95	2.25	Minimum Forearm Girth
Lower Leg Length (Subt.)	−12.85	2.02	2.29	Acromion to Radiale
Upper Leg (Subt.)	+ 6.90	2.14	2.30	Lower Leg Length
Sitting Supst.	−10.00	2.17	2.34	Lower Arm Girth
Intercristal Bdth.	− 0.86	2.17	2.41	Wrist Girth
Dist. bet. ext. eye ∠s	+ 5.64	2.20	2.43	Upper Arm Girth
Sitting Ht.-Sitting Supst	+ 8.00	2.31	2.46	Lower Arm Lgth. (Subt.)
Ear Breadth	+ 1.23	2.41	2.49	Trichion to Gnathion
Wrist Girth	− 1.10 ±	2.58	2.49	Sitting Ht.-Sitting Supst.

TABLE V. (Cont.)

ANALYSIS OF THE INACCURACY OF THE DIFFERENT MEASUREMENTS.

Col. 2. The average difference between the measurements of M.S. and C.B.D. for the dimensions in Col. 1.

Cols. 3, 4. Quadratic mean of differences divided by mean for meas. × 100.

1 Dimension	2	3	4	5 Dimension
Chest A.P.	− 1.27	2.59	2.63	Upper Leg Lgth.
Vertex Ht.-Supst. Ht.	+ 1.82	2.60	3.02	Chest A.P.
Ear Height	− 0.45	3.10	3.32	Interspinal Bdth.
Inter. Mallelous Ht.	+10.40	3.27	3.34	Nasion to Sub
Nose Breadth	+ 0.01	3.34	3.71	Nose Breadth
Nasion to Stomion	+ 5.64	3.38	3.94	Inter. Mallelous Ht.
Dist. bet. intern. eye ∠s	+ 1.80	3.82	4.10	Intercristal Bdth.
Mouth Width	+ 1.73	3.89	4.24	Dist. bet. intern. eye ∠s
Nasion to Subnasale	+ 5.18	4.42	4.31	Mouth Width
Interspinal Bdth.	+ 7.41	6.39	4.82	Nose Depth.
Nose Salient	+ 2.45	6.71	6.28	Ear Bdth.
Nose Depth	− 0.05	6.88	7.59	Lip thickness
Lip thickness	+ 0.59	9.25	9.22	Nose salient

TABLE VI.

AVERAGE OF DIFFERENCES BETWEEN TWO REPEATED MEASUREMENTS OF THE SAME INDIVIDUAL.

	Average of the differences in millimeters			
Dimensions	C.B.D.	M.S.	G.D.	S.D.
Head length	1.55	.64	.51	.40
Head breadth	1.18	.18	.54	.54
Frontal minimum diameter	1.91	.73	1.38	1.25
Face breadth	1.36	.64	.69	.44
Bigonial diameter	1.64	.64	.65	.73
Face length	3.70	1.00	1.52	1.36
Stature	5.09	5.91	3.56	4.57
Sternal height	8.55	9.18	4.25	5.39
Height of symphysis	——	——	4.53	8.06
Height of acromion	10.55	4.45	4.61	6.00
Height of tip of middle finger	9.55	7.27	5.09	6.38
Length of arm	4.90	3.73	4.03	6.41
Length of trunk	3.36	6.09	5.83	9.09
Biacromial diameter	5.73	5.00	3.31	2.99
Bicristal diameter	9.73	4.73	1.64	1.81

C.B.D. C.B. Davenport
M.S. Morris Steggerda
G.D. Gunnar Dahlberg
S.D. Mrs. G. Dahlberg

accounted for by the fact that M. S. has been measuring continously during some two hundred days of the year, whereas C.B.D. measures only during about thirty days of the year.

Table VI gives the average of differences between two repeated measurements of the same individual by the two measurers, C. B. D. and M.S.; and, in comparison, measurements made by G.D. and S.D., as recorded in the work of Dahlberg, 1928. This table shows that these absolute differences range from 0.2 to 10.55 mm. The smaller differences are obtained, of course, in head length and breadth, and face breadth. The larger differences are, as would be expected, obtained for the most part in the larger dimensions such as length of trunk, height of acromion, height of tip of middle finger from the floor.

Summary of Part II.

1. The absolute inaccuracy of different measurements varies in part directly with absolute size.
2. The percentage inaccuracy varies greatly. It is low in large dimensions, like stature; high in small dimensions, like lip thickness and nose dimensions.
3. The inaccuracy is partly inherent; due sometimes to the absence of sufficiently precise landmarks, sometimes to difficulty in securing uniform posture. Thus, waist girth, chest diameters, interspinal width, intercristal width, length of arm and leg segments, suprasternal height (sitting) are among the least precise of the measurements.
4. There is a significant personal equation in the measuring by different anthropometrists, even those who have had similar training. This is due sometimes to differences in the "setting up" of the subject; sometimes to the use of slightly different landmarks; sometimes to subjective differences in the measurers.
5. As in other occupations so in measurement of the body continual practice leads to increased precision.

Discussion.

If there is to be a science of physical anthropology, attention must be focussed on methods of measurement. There must be agreement upon what to measure and how to measure, and there must be known the personal equation of the measurer.

A. TECHNICAL MATTERS WHICH NEED TO BE STANDARDIZED ARE:

1. The posture of the subject as a whole and in respect to each dimension measured. For example: How shall the subject sit in measuring sitting height? How shall he stand in measuring foot length? How shall the arm be held in measuring length of the lower arm?

2. The definition of landmarks. Many of these have been defined in Martin's ('28) textbook; but in many cases the definitions are far from adequate. For example, "Iliospinale ant., the most downwards directed point of the Spina ili. ant. sup." and "the Interspinal dimension is the straightline distance between the two iliospinalia ant. from each other." Now the iliac "spines" are 6 to 8 mm. thick and it makes a difference whether one measures to the lateral or the median surface of the spine. If one is to measure to the middle of the spine that constitutes a rough landmark. A score or more inadequate descriptions of this sort from Martin ('28) might be cited. All landmarks should be defined to within a millimeter or two.

3. The handling of moveable landmarks. Few of the landmarks commonly used are fixed. For example, thelion is defined as the center of the nipple. That would seem to be precise. But the nipple, in respiration, moves through a considerable arc and its height varies accordingly. The "at rest" position is not a thoroughly adequate definition: for the chest does move even at light breathing. Another instance: In measuring radiale to stylion how shall the plane of the hand lie in reference to the sagittal plane of the body?

4. The degree of pressure at the skin and tissues to be applied over bony landmarks. This is a topic which Miss Tildesley has stressed; and a tape has been devised with a spring to provide a standard tension. Such an instrument is slower to manipulate than an ordinary tape, and the error in posture and location of the girth to be measured are generally greater than that of skin pressure, e. g. the level for girth of upper arm, the maximum girth of lower arm, thigh girth, calf girth.

5. Alternative dimensions. There are frequently two or more ways to measure an organ. Agreement should be made as to standard dimensions. For example, the segments of the arm may be measured (in projection) from the floor or directly with the large calipers ("Stangenzirkel"). Again, thigh girth may be measured at gluteal fold or just below or wherever is maximum girth.

6. Alternative techniques. The handling of the instruments to

determine the dimensions. This is a somewhat complex subject, it involves (1) the best instrument to use, (2) the best way to apply. For example, foot length may be measured with the anthropometer as calipers, the foot free; or with the depth measurer, heel applied to wall or box; or the contour of the foot may be traced on paper with a split pencil and this outline measured. This latter gives a *record* of the form of the foot, but the dimension of the outline tend to be 2–3 mm. too great.

B. CHECKING OF MEASUREMENTS.

a. Repetition. A single measurement of any dimension has a very limited value because of limitations in accuracy in making the measurement, because of possible imperfections or errors in finding landmarks, in reading the measuring scale, in recording, etc. Not until the whole set of observations has been repeated can one judge how accurate, or how inaccurate, the first set of observations may be. In our own measurements we have always taken stature three times in quick succession, each time warning the subject to stand straight. The largest of the satisfactorily determined measures obtained is used as the stature of the individual. Since stature is used in many indices it is essential that it should be as nearly correct as possible. If one has the opportunity of making frequent remeasurements of the same individual, usually a growing individual, each successive measurement serves as a rough check upon each other. We do not feel that any set of measurements taken on an adult is entirely trustworthy until it has been repeated.

A fairly satisfactory method of checking any bilateral organs is making measurements on both sides of the body. If the asymmetry appears marked then the measurements should be rechecked. Organs in the sagittal plane can sometimes be measured on both sides of that plane. Thus nose depth is determined by measuring the depth of the nose both from the right cheek and from the left; similarly the depth of the nose bridge from the inner angle of the eye is measured both on the right side and on the left side, and the average of the two measurements taken.

b. A second method of checking measurements is by securing the size of the dimension by two or more methods. For example, head height can be measured either with the head height instrument or by subtracting tragion height from vertex height. If findings by the two methods do not agree, it is necessary to find out why and remeasure until they do agree. Similarly, nose salient may be measured di-

rectly from the upper lip, or the salient may be obtained by use of the depth measurer with the occiput against the wall and subtracting the distance: upper-lip-from-the wall from the distance tip-of-nose-from-the wall. If the results of the two methods of measuring are dissimilar they should be repeated until alike. The foregoing are examples of principle of checking which deserves to be widely adopted. Again, the length of the different segments of the arm may be obtained by measuring the distance from the floor of the critical landmarks: acromion—radiale—stylion. Owing to the fact that the acromion is very mobile it is desirable after the heights of the landmarks have been determined (starting with the acromion and proceeding to stylion) to check again on the acromial height to see that the subject has not moved in the meantime. Also, the measurement should be made on the left arm as well as on the right and the findings of the two arms should ordinarily be fairly close.

Of course the segments of the arm should be measured directly. These findings serve as a rough check on the measurements indirectly from the floor, but the measurements will not agree precisely because the measurements from the floor give projections of the length of the segments of the arm, and where the arm can not be straightened the projection may be much less than the true distance.

Every effort should, of course, be made to avoid errors, but a certain degree of error is inevitable. There are errors in the posture of the individual, errors in angular positions of the instruments, errors in reading of the instruments due to imperfect light or owing to bad illumination which may throw the reading at least 1 mm. out; blunders in calling off numbers in poor light as, for example, confusing a 3 and an 8, errors in hearing and recording. The principle has to be kept in mind, as stated above, that a single set of measurements has an unknown value.

c. Securing the comparability of the measurements of different operators and determining their personal equations. It is depressing to recognize that there are scores of anthropometrists in different parts of the world measuring by more or less different landmarks, with widely different techniques and publishing results without defining their technical methods. The consequence is that the published results of different authors cannot be closely compared, also these measurements are for the most part taken without checking so that the value of the determinations cannot be determined.

The only way, apparently, to secure the comparability of methods

is through the Congresses where a number of anthropometrists meet and agree upon the technical details necessary to secure that comparability.

C. CHANGE IN DIMENSIONS ASSOCIATED WITH SEASON.

Although our special data did not involve changing seasons yet for the sake of rounding out the subject the effect of season has to be

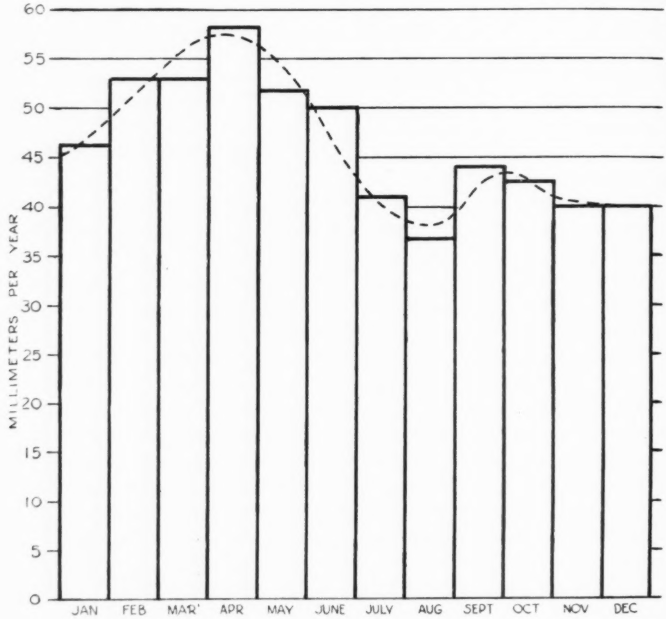

FIGURE 1. Increases for each month in stature centered at middle of increment period and calculated on a yearly basis. (LVD II ♂)

considered. The topic, far from new (see Nylin, '29), is of more than academic importance in the study of the growth of children who are measured repeatedly at different months of the year. Our contribution to this subject is based on studies of children, mostly at Letchworth Village, measured repeatedly mostly at 6-month, sometimes at

4- or 3-month, intervals. We shall consider here only stature and weight.

a. *Stature.*

Our data permit two methods of judging the influence of season. One is that of comparing the increments made during certain periods calculated on a yearly basis, and assigning such increments to the central month of the period. Thus, if a boy was 1342 mm. tall in

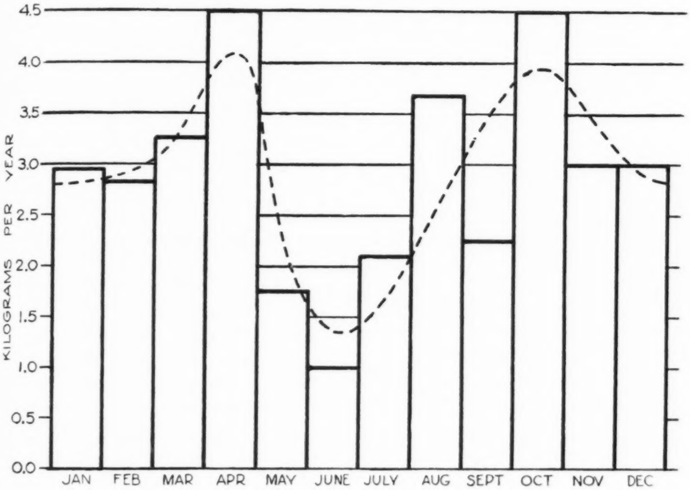

FIGURE 2. Increases, month by month, in weight, centered at middle of increment period and calculated on a yearly basis. (LVD II ♂)

October and 1370 mm. tall in the following April, he had increased 28 mm. in 6 months, or at the rate of 56 mm. per year, and this increment was assigned to the month of January. When all the assignments had been made, the median rate per year was calculated for each month.

The results are shown in Fig. 1. These results indicate that, on the average, stature makes its greatest gains, with us, in the spring of the year and its least gains in late summer. This result agrees with the findings of Camerer (1893), Schiötz (1922) A. and K. E. Schreiner (1922) and G. Nylin (1929); not so well with those of Porter (1920).

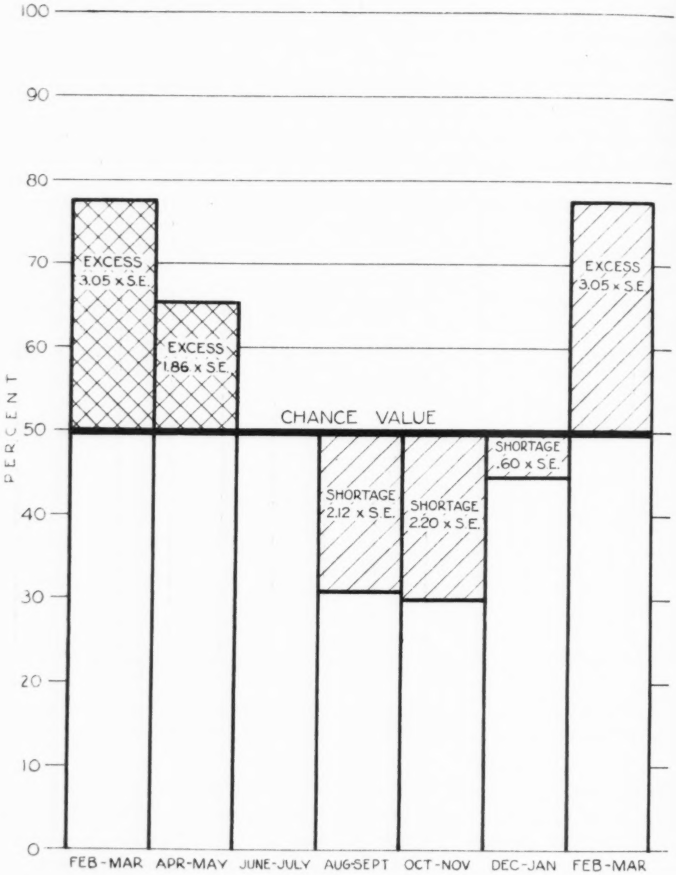

FIGURE 3. Departure from chance values of frequency of peaks of stature-growth in different months. The significance of the difference between the number of peaks and depressions occurring in each bimonthly period was found by computing the standard error of the difference between the actual values and the chance values. (LVD♂).

b. *Weight.*

The results for body weight are given in Fig. 2. This shows two main periods of increase of weight, one in the spring corresponds to the period of increase in stature; the other in the autumn corresponding to a slight increase in stature that occurs at that time. The period of least increase in weight comes in June, while that of least increase in stature is in August. This suggests that growth in weight is more quickly disturbed by summer conditions than growth in stature. Also it appears that weight increases heavily (on the average) in the autumn, but the rate of growth of stature is relatively little accelerated at this time. This agrees with the findings of Nylin (1929) and of Palmer (1933).

The slowing up of weight-increase in the summer at Letchworth Village must be considered in relation to the activities of the children at that time. This is the period when the boys engage in work in the fields, some of it quite hard, at least a favorable change from the indoor work or relative inactivity of the winter and early spring.

The increase in weight of the autumn is perhaps a physiological preparation of the body for protection against winter cold. Since stature shows no great spurt at this time body build must increase.

The other method employed was that of counting the number of peaks and depressions of stature (or weight) occurring in each bimonthly period and comparing them with chance equality. The results in bimonthly periods are given in Fig. 3. This indicates that the spurts of growth are more apt to be centered in the spring months than in the autumn months. Thus this second method confirms the first.

We conclude then that growth in stature in our series is most rapid in the spring; while growth in weight is most rapid at the same time and also hardly less so in the autumn. There is a physiological need for autumnal acceleration in weight that hardly exists for stature.

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